



Final report of the Chesapeake Bay Scientific and
 Technical Advisory Committee's workshop:
 Understanding "Lag Times" Affecting the Improvement of
 Water Quality in the Chesapeake Bay

January 2005



STAC Publication 05-001

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The STAC provides scientific and technical guidance to the Chesapeake Bay Program on measures to restore and protect the Chesapeake Bay. As an advisory committee, STAC reports quarterly to the Implementation Committee and annually to the Executive Council. STAC members come primarily from universities, research institutions, and federal agencies. Members are selected on the basis of their disciplines, perspectives, and information resources needed by the Chesapeake Bay Program.

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and Technical Advisory Committee's workshop:
Understanding "Lag Times" Affecting the
Improvement of Water Quality in the Chesapeake
Bay

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Sponsored by
The Scientific and Technical Advisory Committee (STAC)

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Executive Summary

Better quantifying the “lag time” between changes in nutrient and sediment sources in the Chesapeake Bay watershed and improvement in the Bay’s water quality and submerged aquatic vegetation (SAV) is critical to help resource managers to implement the most effective nutrient and sediment reduction strategies and for scientists to improve monitoring and modeling. Tributary strategy plans for basins within the Bay watershed have been developed to implement appropriate best management practices (BMPs) to reduce nutrient and sediment loads to the Bay. These practices are designed so water-quality criteria (for dissolved oxygen, water clarity, and chlorophyll) can be met in the Bay by 2010. However, there is a large degree of uncertainty about the “lag time” between implementing the nutrient and sediment practices and detecting an actual improvement of water quality and SAV in the Bay. There are several components of “lag time” including:

- a. The time between planning and implementation of a management practice;
- b. The influence of watershed properties on movement of nutrients and sediment to the Bay; and
- c. The time between a load reduction to the Bay and the actual improvement in water quality and SAV.

Results from the workshop suggest that “lag times” associated with implementation of management practices, impacts of watershed properties, and response of the Bay water quality will make it very difficult to meet water-quality criteria in the Bay by 2010. There are substantial time periods in the planning (15 months), implementation (1-3 years), and then attainment of maximum efficiencies (1-10 years) for most BMPs identified in an individual tributary strategy plan. Additionally, there are lag times associated with the movement of nutrients and sediment in the watershed. These include the influence of ground water that may cause a lag time from months to decades for improvement in nitrogen concentrations. Watershed properties affecting the storage and transport of phosphorus and sediment may cause lag times of years to decades in water-quality improvements. Lag times in the tidal waters appear to be much shorter. The findings suggest that water-quality conditions in tidal waters may improve within a season as nutrient and sediment loadings are reduced to the Bay.

Implications and recommendations: The information about lag times can be used by resource managers to prioritize implementation of practices that provide the most rapid improvement in water quality and improve models and monitoring. The recommendations include:

- (1) Actions to reduce nutrients from point-source discharges by utilizing excess capacity at municipal treatment plants may provide the most rapid improvement in water quality in the receiving waters;
- (2) Practices to reduce nonpoint sources should be assessed to determine which practices may provide the most rapid improvement in water quality given the watershed characteristics of a tributary strategy basin. This assessment can be used in conjunction with the cost effectiveness of a BMP to help determine priorities for implementation of specific BMPs in individual tributary basins;
- (3) The CBP should support a thorough evaluation of the suite of BMPs accepted for consideration by the jurisdictions in terms of time required for selecting and building the

BMP, lag before the BMP begins to remove sediment or nutrient, and the subsequent length of time expected before a detectable change in receiving water loads might be observed. These results, in turn, should be incorporated into subsequent Phase 5 watershed model runs. This evaluation would be valuable to help prioritize funding for implementation of BMPs in the most critical areas of benefit in the watershed;

- (4) For a more realistic assessment of predicted improvement in water-quality progress, model runs might be conducted with actual lag times for BMP planning, implementation, and time to maximum efficiency built in for each tributary;
- (5) Models could also be improved by better simulating the watershed processes that affect nutrient and sediment delivery to the Bay;
- (6) Interpretation of monitoring data needs to better explain the factors affecting water quality changes in the Bay and its watershed.
- (7) Assessment of tidal data for attainment of water-quality criteria needs further to consider impacts of extreme and prolonged hydrologic events to provide an objective assessment of water quality conditions in the Bay.
- (8) The CBP should develop an approach to communicate the implications of the lag time between management actions, watershed properties, and cycles in weather conditions on the restoration of the Chesapeake Bay. This will be very important for continued support of efforts to implement BMPs even though the results of these actions often will not be immediately observed.

Workshop Objectives

The objectives of the STAC Lag Time Workshop were to (1) provide the CBP with a better understanding of the factors affecting the “lag time” associated with improving water quality and SAV in the Bay and (2) provide recommendations for improved monitoring and modeling of these factors. By holding this workshop in 2004, the information will be available for use to help improve development of monitoring and modeling approaches and implementation of tributary strategies. The workshop included sessions for each of the major “lag time” components:

- The time between planning and implementation of a management practice;
- The influence of watershed properties on movement of nutrients and sediment to the Bay; and
- The time between a load reduction to the Bay and the actual improvement in water quality and SAV.

Session 1 Summary

Planning and Implementation of Management Practices

Session Chair: Ron Korcak, USDA-Agricultural Research Service, Beltsville, Maryland

Speakers:

Cliff Randall, Virginia Tech (retired): Implementation of Point Source Nutrient Controls.

Mike Bowman, VA Department of Conservation and Recreation; and Gary Shenk, Chesapeake Bay Program: Non-point sources – Tributary Strategies and the Bay Watershed Model: Accounting for management practices.

Mark Waggoner, Natural Resources Conservation Service: From planning to Implementation

Questions to be addressed by the session:

1. What have been the most commonly adopted practices to date and what is the projected for adoption to 2010?
2. What is the lag time between planning and actual implementation? What is the actual extent of implementation (% of the planned activities)?
3. Are the funding and technical assistance resources available to achieve the implementation by 2010 or by 2015?
4. What are recommendations to refine the simulation in the CB model that would improve the correspondence between the actual point source and non-point source practice implementation and the model accounting?

Summary of Results

Point Sources

There are over 304 significant, municipally-owned wastewater treatment plants in the Chesapeake Bay Watershed. Currently only about 75 wastewater treatment plants are using nutrient reduction technologies and it is projected that this number will double by 2010.

Of importance is that most of the 304 municipally owned wastewater treatment plants have excess treatment capacity, on the order of 60%. This excess capacity could be utilized for rapid, low cost implementation of biological nutrient removal (BNR) and/or limits of treatment nutrient removal. The perceived modification costs are the primary obstacle to implementation of nutrient removal technologies. However, the York River wastewater treatment plant is an example where excess capacity was used to accelerate implementation of nutrient removal by implementing reasonably cost biological nutrient removal modifications.

The lag time between planning and actual implementation of point-source reductions depends if a facility adopts an approach to utilize excess capacity to implement BNR or if major construction is required. Estimated times for undertaking most renovations are 1 year if excess capacity could be utilized for rapid, low cost implementation of BNR at a plant. If major construction is required at the plant, the lag time can be 3-5 years between planning and implementation of point-source reductions.

There exists a major opportunity for the Bay Community to upgrade point source facilities and have a significant impact on nutrient loads to the system. The technology for these upgrades exists; what appear to limit upgrades are financial considerations. For instance, the capacity of any wastewater treatment plant is the basis for bank loan funding. If the total load capacity of a facility decreases through the use of its excess capacity to accelerate implementation of nitrogen removal, the loan eligibility for the plant declines. The improved nutrient removal is not a consideration for loan amount. Therefore, owners will resist utilizing excess capacity to remove nutrients due potential reduction of financial borrowing potential. However, if there is a court order or other mandate, implementation of nutrient removal strategies will be done as mandated regulations result in rapid compliance.

The recommended strategy to reduce costs and accelerate implementation of point source nutrient removal includes the following:

- Provide immediate funding for use of Excess Capacity.
- Develop a guaranteed long-term funding strategy for owners as plants reach capacity, specifically to include enhanced load potential for increased nutrient removal through low-cost use of excess capacity for nutrient reduction.
- Economic analyses of plant operations and economic assessment must permit a reduction of operating and maintenance costs with adoption of the more efficient nutrient removal technologies.
- Utilize existing excess capacities of the significant wastewater treatment plants to:
Reduce the costs and accelerate implementation of biological nutrient
Removal and limits of treatment nutrient removal at the significant wastewater
treatment plants in the Bay watershed.

Enable point-to-point nutrient trading.

- Inaugurate a water-savings program to further increase excess capacity.
- Supplement excess capacities with innovative treatment technologies.
- Utilize centralized sludge processing wherever feasible.
- Incorporate recycle, reuse, and recovery methodologies.

Using these strategies along with existing and proven technologies for nutrient removal in combination with either a strategic (financial incentives) or tactical (regulatory requirements) approach will have a significant impact in reducing point source nutrient inputs in the Bay Watershed.

Non-point Sources

There are numerous, commonly adopted management practices in the Chesapeake Bay watershed to reduce nutrient and/or sediment loads. These practices include: reduction of nutrients through conservation plans and nutrient-management plans, cover crops, forest buffers, grass buffers, animal waste management systems, erosion and sediment control structures, and storm-water management. These practices are encouraged but there is a lag time between planning, implementation, and effectiveness of a practice, or suite of practices, to reduce nutrients and sediment.

The lag time from planning to actual implementation of management practices can be from days to years and depends on: Planning at the field scale (what, where, how), selection of the appropriate best management practice (BMP), plan preparation, and, finally, implementation. Because every site is unique and requires a specific set of BMPs to meet off-site water quality objectives, the planning process can take between 6 months to 2 years. Once planned, implementation of some individual practices can be accomplished in a very short period times (days). However, many areas require a suite of practices that results in a conservation system that may take years to implement. Additionally, the suite of practices may have a lag time before they reach their peak efficiency. For example, riparian forest buffers may take years to mature and reach maximum efficiency due to the growth rates of the trees.

There are a number of factors that can influence the implementation of BMPs and, in turn, impact the lag time from planning to implementation. These factors include on-site timing for agronomic practices, cost-share availability and criteria, other farm practice changes required, and whether or not the land is rented. It is estimated that between 20% and 60% of the cropland in the Chesapeake Bay watershed is rented annually. In these situations, there may not be clear incentives and responsibilities for land owners and renters to install and pay for BMPs.

The resources do not currently exist to achieve full implementation of management practices by 2010 or 2015. One of the causes for the delay is a lack of technical staff and funding to plan, design, construct, certify, and verify management practices. Further, there is considerable resistance to rapid BMP implementation through at least two other factors, limited dialog with

farmers on the duration that a practice should be in place and limited funding (subsidies, remuneration for putting land into a BMP and out of production) to assist the farmer in adopting and maintaining the practice.

Assessing the effectiveness of management practices is complex. The CBP works closely with the jurisdictions to document the amount of practices in the watershed. The simulation of nitrogen, phosphorus, and sediment cycling and loading is accomplished primarily through use of the Hydrologic Simulation Program-FORTRAN (HSPF) model that is used for the CBP WaterShed Model (WSM). The CBP WSM is then used to estimate reductions of nutrient and sediment based on information about implementation of management practices. The time between gathering and verifying the management practice data and conducting CBP watershed model progress runs can take 6 to 15 months. As an example, implementation progress data for 2002 is reported by mid-July 2003. However, final approval and release is not achieved until March 2004, a lag time of 15 months.

The CBP WSM development and application poses an effective means to 'estimate' BMP effects on the watershed although there are concerns. The simulation of management practice efficiencies in the WSM is one concern. While research plots provide ideal efficiencies for these practices, actual field efficiencies for most of the practices on a farm are not known and it is expected that in practice, lower efficiencies are likely extending the time for reaching desired load reductions in the tributary strategies. Another important area for review is the basic 10-year hydrology approach that is used. The model runs a 10-year hydrology before and after BMP implementation, the latter derived from tributary strategies. Therefore, the post-BMP output reflects maximum BMP effectiveness over the 10-year period when, in fact, the strategies are 'planned' activities and there is no lag built into the model for maturation of the BMP to its maximum effectiveness. Model output, therefore, represents load reductions from full implementation of all management practices. Another concern is the assignment of a BMP for individual model segments. There is no reasonable way to account for the geographic placement of BMPs within a model segment thereby homogenizing BMP effectiveness.

Finally, there is some concern about the actual BMP implementation 'on the ground' in the jurisdictions. Implementation of some of these practices is difficult to track and therefore there is uncertainty about the amount of management practices that have been implemented. For example, in 2002, tributary strategies called for over 6 million acres to be under conservation plans but implementation approximated 3.6 million acres. Similar differences were noted for all other management practices with the possible exception of conservation tillage where tributary strategies called for about 2.2 million acres and 2 million acres were actually implemented in 2002. Also, current tributary strategies fall short on maximum implementation, by 2010, of all management practices. The main problem aside from insufficient funds for all BMPs is currently minimal field verification that planned BMPs are actually implemented.

Session 2 Summary

Influence of Watershed Properties on Water-Quality Response

Session Chair: Scott Phillips, U.S. Geological Survey (USGS)

Speakers:

Jeff Raffensperger USGS and Gary Shenk, CBP: Simulation of sources and transport of nutrient and sediment in the Bay watershed and ideas for improvement.

Bruce Lindsey, USGS: The discharge, nitrogen load, and residence time of ground water in the Chesapeake Bay watershed.

Allen Gellis, USGS: Source, transport, and storage of sediment in the Bay watershed.

Don Boesch, University of Maryland Center for Environmental Science: Findings from STAC's *Chesapeake Futures*, Recent trends in land use and development and implications for nutrient loads and response of Chesapeake Bay

Questions to be addressed during the session:

1. What are the major sources, amounts, and projected future changes of nitrogen, phosphorus, and sediment in the Bay watershed?
2. What are the amount, associated residence times, and factors influencing nitrogen, phosphorus, and sediment sources associated with the different transport pathways in the watershed?
3. How these processes are simulated in the current management models and what are some other possibilities for improvement?
4. What is the ability of monitoring networks to detect changes in water quality as sources are reduced and what are some of the current trends?
5. Based on these transport times, what are the implications for water-quality response in the watershed?

The purpose of this session was to present information about (1) the sources of nitrogen, phosphorus, and sediment, (2) the residence time and factors influencing the movement of these pollutants through the watershed, (3) how the processes are simulated in current management models, (4) the ability of monitoring networks to detect changes in water quality as the sources are reduced, and (5) the implications for water quality response in the watershed.

Summary of Results

The major contributors of nitrogen, phosphorus, and sediment vary in the Bay watershed. The Chesapeake Bay Program (CBP) WaterShed Model (WSM) is one tool to provide estimates of different sources of nutrients to the Bay. For nitrogen, about 20 percent is from point sources and 80 percent from non-point sources. The non-point sources can be further divided into about

32 percent from the atmosphere and 48 percent from other non-point sources. Of these remaining nonpoint sources, fertilizer and manure comprise the majority. For phosphorus, there are similar percentages for point sources (22%) and non-point sources (78%). The non-point sources can be divided into urban (16%), mixed open (11%), agriculture (48%), forest (2%), and a small amount from the atmosphere (1%). The sources of nitrogen and phosphorus associated with point-source discharges will mostly likely increase over time as the human population in the watershed increases from current levels of 15 million toward projections of 18 million by 2030.

The sources of sediment are less well defined. Sources of sediment to the Bay include shoreline erosion, delivery from the watershed (from disturbed agricultural and urban lands and stream corridors), input from the ocean, and internal biogenic production (Langland and Cronin 2003). The relative contribution from these sources differs in different areas of the Bay. In general, the Susquehanna River is the dominant source of sediment in the northern Bay, in the southern Bay, shoreline erosion and input from the ocean are the dominant sources, and in the central Bay, shoreline erosion dominates.

The residence time of nitrogen from the source to the Bay is impacted mostly by the amount of nitrogen in surface and ground water. On average, about 50 percent of the nitrogen from the land surface will runoff into surface water and the remaining 50 percent will percolate into the shallow ground water (Bachman et al. 1998). Once nitrogen is in the shallow ground water, the length of time it takes to be discharged into tributaries will depend on the movement and age of ground water. The age of ground water in the uppermost aquifers in the Bay watershed range from modern (most nitrate rich, less than 1 year) to more than 50 years (lower nitrate water), with a median age of 10 years (Lindsey et al. 2003). These residence times and the amount of associated nitrogen will differ among streams depending on the sources of nitrogen in a watershed and the properties affecting runoff and movement of ground water. For example, in some areas of the Delmarva Peninsula, a large amount of the ground water discharge to streams is fairly young (less than 10 years) and contains nitrogen due to excess manure, so BMPs to remove the source of manure may result in fairly rapid improvements in water quality. However, other areas on the Delmarva (and in the watershed) have older waters (greater than 10 years) that have been impacted by commercial fertilizers. In these areas, there will be longer lag times between the application of management practices and improvements in water quality. In addition to the source reduction, nitrogen can be removed from the ground water due to natural processes such as denitrification. The interchange of factors (ground water age, denitrification, type of source, aquifer properties) can result in a less-than-expected reduction of nutrients in receiving waters even in areas with extensive implementation of management practices.

Residence times for phosphorus and sediment are closely related but not well documented. The amount of dissolved phosphorus discharged from point sources directly into a stream will have relatively short (days to weeks) lag time from its source to the Bay. This is estimated to be a fairly small amount (about 20 percent) of the phosphorus in the watershed. Phosphorus associated with sediment will have residence times from days to decades, because much of the sediment (and associated phosphorus) is stored in the watershed after it has been eroded from the land surface. Estimates of the amount of storage range from 75 % in small basins (10 km²) to over 90 % in larger basins (>100 km²). The movement of sediment and phosphorus will then

depend on storm events that transport sediment from upland sources through different stream reaches and finally the Bay.

The simulation of nitrogen, phosphorus, and sediment is accomplished primarily through use of the CBP WSM. The model is a watershed water-quality model originally developed as a rainfall-runoff model. The Hydrologic Simulation Program-FORTRAN (HSPF) model simulates a fairly rapid transport of ground water and the associated nitrogen. The active ground water zone in HSPF has a very short residence time (hours). Investigators are trying to improve the simulation by adding an inactive ground water zone that will increase the apparent residence time. Current simulations result in a more constant concentration in ground water but there are several possibilities to consider for improving the simulation including: (1) using a constant 10-year ground water residence time, (2) determining ground-water residence times from recession or hydrograph separation, and (3) considering changes due to different watershed characteristics. Actions are being taken in the CBP Phase 5 WSM to improve this simulation. Simulation of phosphorus and sediment transport is based on the impact of rainfall in eroding sediment from the land surface and transport based on stream discharge during storm events. Further, the ground water residence time issue is so important that exploration of other models perhaps linking to HSPF needs to be explored.

Monitoring of nutrients and sediment in the watershed to detect changes over time has been limited to about 30 stations in the watershed. At a subset of these stations, storm samples are collected, indicating the limited monitoring of sediment and phosphorus during critical transport periods. In 2004, the CBP is implementing an enhanced non-tidal water quality network in the Bay watershed. Initially, about 100 sites will be monitored in the watershed with approximately half of these sites will include storm samples. The ability to detect water quality changes in the watershed will improve as the spatially and temporally more intensive network is implemented. Further interpretation of the monitoring data will be accomplished by using models and other data sets to understand the factors affecting water-quality changes over time.

Based on residence times associated with nutrient and sediment in the watershed, several conclusions can be made concerning water-quality improvements and implications for management actions. Meeting the proposed water-quality criteria by 2010 will be very difficult given the lag times noted above that affect nutrients and sediment in the watershed. Some of the management implications are that the most rapid improvements in water quality would be from reduction of point sources of nitrogen and phosphorus. Once point-source reductions are implemented, there would be almost instantaneous improvement of water quality in the receiving water body. However, point sources represent only about 20 % of the nitrogen and phosphorus delivered to the Bay. Improvement in water quality from non-point source reductions will take longer and in the long run, as the largest load contributor, be most important to the Bay's restoration. Improvements in water quality of streams for the portion of nitrogen that runs off directly into streams or shallow soils could take hours to months once management practices are fully implemented. However, the remaining nitrogen in the ground water system could take about a decade (on average) to show improvements to management actions. Water-quality improvements related to nutrients associated with sediment could take longer, given the amount of storage in the watershed and its movement with storm events. Resource managers may want to

consider implementing sediment reduction practices near the Bay and tidal tributaries to help compensate for these long residence times for sediment.

Session 3 Summary

Climate variability, load reductions, and improvement in tidal water quality and SAV

Session Chair: Kevin Sellner, Chesapeake Research Consortium

Speakers and Panel:

Walter Boynton, University of Maryland Center for Environmental Science, Chesapeake Biological Lab;

Bill Dennison, University of Maryland Center for Environmental Science;

Bruce Michael, Maryland Department of Natural Resources;

Charles Gallegos, Smithsonian Environmental Research Center

Summary of Results

Tidal Water Responses

Material presented at the workshop suggests that tidal responses in dissolved oxygen (DO), chlorophyll, water clarity and submerged aquatic vegetation (SAV) will be very rapid, and in some cases the responses will be within season or seasons, not years. These results were derived from examining tidal responses to high and low flow years over the last 40 years. In general, tidal chlorophyll levels, DO in the deeper parts of several tributaries and the mainstem Bay, and SAV respond fairly quickly to reduced nutrient and sediment loads to the Bay. The loads are a function of changes in stream flow and concentrations. Two examples of relatively rapid improvements include dissolved oxygen and SAV responses in the Bay during the drought years of 1999-2002 which provided a natural condition of lower nutrient and sediment loads to the Bay due to lower river flow.

Several factors were identified for the rapid seasonal responsiveness of dissolved oxygen in the Bay and several of its tidal tributaries. First, nutrient loads are highly correlated with river discharge, not surprising but important to understanding subsequent water quality and living resource responses in tidal waters. Second, there is little evidence suggesting there are long-term nutrient stores in the tidal sediments so therefore, nutrients entering during the winter and spring largely support within year water-quality changes. Third, nutrient flux, critical to high summer productivities in the tidal waters, is strongly correlated to chlorophyll from the previous month, further emphasizing the importance of system responses within a season. Fourth, for the Bay and four MD tidal tributaries, chlorophyll biomass is strongly tied to river discharge, residence time in the river/estuary, and nutrient load and hence, system biomass is closely coupled to nutrients entering the system. Lastly, summer hypoxic volume and therefore DO levels are strongly tied to river discharge (Patuxent and mainstem Bay), not surprising considering the strong relationship between nutrient load and biomass, which is the 'fuel' for oxygen consumption at depth in the tidal waters.

In a similar manner, SAV responses seem to occur within growing seasons. There were increases in SAV acres during the drought conditions of 1999-2003 when water clarity improved

due to lower amount of nutrients and sediment entering the Bay. In contrast, the acres of SAV in the Bay declined by about 30% in 2003 largely due to elevated freshwater flows and the accompanying increase in loads of suspended sediments and nutrients. Further, P and particularly N reductions in the tidal waters of the upper Patuxent River have been followed by a rapid increase in tidal-fresh mixed SAV, indicating that load reductions should manifest themselves with fairly rapid increases in these valued plants and the associated habitat and sediment/nutrient clearing capacity. In addition to improved water clarity, the SAV response will also be influenced by the amount of propagules in an area. The multiple factors affecting water clarity and the 15 different species of SAV in the Bay will impact the overall lag time between nutrient and sediment loads reductions and the growth in SAV. While some responses are detected within one season, increases in different species can take up to several years. The actual mechanisms for the relationship between all the factors and increase in SAV remain to be determined through rigorous examinations of nutrients, sediment, water clarity, and SAV species changes in specific geographic areas.

Local and/or Extreme Events

The tributary strategies provide plans for long-term reductions in nutrient and sediment concentrations in the Bay and its major rivers and if implemented, conceivable reductions in both should occur with a corresponding rapid system response. However, BMPs will reduce nutrients and sediments concentrations slowly over time, and with the rapid changes of weather and river discharge, immediate, detectable responses in the rivers and tidal waters may be masked by changes due to natural variability.

There are numerous examples of basin events resulting in dramatic, detectable occurrences that if not explained to the public, could seriously jeopardize their continued commitment to slow-acting BMPs essential to the basin's restoration. Major storms can deliver large loads of nutrient and sediment to the Bay and its tidal tributaries from the watershed leading to immediate water quality and SAV responses that persist into the following year. One example is the effect of Tropical Storm Agnes (June, 1972) that contributed to a large loss of SAV. The high flow year of 2003, preceded by 4 years of drought, provides a more recent example. Small, down-bay tributaries can react to pulses of nutrient delivered from unexpected spring storms in the Susquehanna basin where nitrate-enriched waters are transported southerly along the west coast of the Bay leading to intrusions and phytoplankton blooms in western shore systems (Gallegos et al, 1992). Tributary strategy plans could not address these loads nor should the jurisdictions be held responsible for these events as they occur independent of, and external to, local practices implemented in the system. Hence, there need to be procedures to accommodate unexpected natural events that would appear to lead to water quality criteria exceedance regardless of managed BMPs in the watershed or segment.

The CBP has developed a strategy that permits some degree of criteria exceedance that could be due to an event beyond the control of BMPs. The approach is based on a cumulative frequency distribution (CFD) of water quality criterion exceedances. The approach includes a comparison of a CFD in a healthy area to that in a suspect area and is designed to allow for short term, wide-spread impacts that could be caused by factors such as large meteorological events. Criteria exceedances caused by such an event would be considered "allowable" because they are not the result of any human action and often would not have long-term impacts on ecological integrity

because of their short duration. For example, if a major storm impacts a region resulting in elevated chlorophyll levels over a substantial portion of the region after the storm's passage, this would be a short-term, readily observable post-storm phenomenon. However, as it occurs for such a short time in the system, relative to the year's chlorophyll levels, the increase would be only a minor contributor to the annual chlorophyll levels and hence, not far removed from 'normal' conditions. The event might therefore be considered to be within acceptable variability anticipated for a natural system. Because the natural variability is implicitly captured by a CFD in a healthy system, comparison of CFDs from other areas provides one approach for allowable deviations that do not have lasting ecological impacts.

Summary and Implications

The results presented during the workshop and this session suggests that once nutrient and sediment loads to the Bay are reduced there should be a fairly rapid response of tidal water quality and SAV. However, the time to achieve the load reductions depends on lag times in BMP implementation, BMP effectiveness and maturation, watershed properties, and the influence of annual variability in rainfall and river flow conditions. Therefore, the load reductions to the Bay, especially those related to non-point sources, will take years to be fully achieved. This implies that meeting the water-quality criteria in the Bay by 2010 will be extremely difficult.

Implications for the scientific community

The scientific community needs to improve information related to factors affecting water-quality and living resources in the Bay and its watershed to better inform resource managers about the effectiveness of different BMP strategies and implementation. Modeling within the CBP should continue to be used to predict potential load reductions under different scenarios but there is a need to re-examine its communication of “progress” runs. The current watershed model focuses on assessing load reductions based on *planned* BMP implementation, and assumes maximum efficiencies. More realistic evaluations of BMP effectiveness, specifically the 1) actual sites where BMPs are on the ground, 2) the length of time required to reach maximum nutrient and sediment load reduction, and 3) better simulation of watershed properties could provide more realistic predictions of load reductions and “progress”. Monitoring needs to be enhanced in the watershed and tidal waters to provide data on water-quality changes as management practices are implemented. Modeling, monitoring, and research need to be further integrated to explain the impact of natural variability, human population growth, and BMP effectiveness on water quality and living resource changes in the Bay and its watershed. With an improved scientific understanding the CBP can continue to adapt management actions to achieve the restoration goals of the *Chesapeake 2000* agreement.

Implications for Tributary Teams and Regional Expectations

The information from this workshop can be used to help tributary strategy teams to better prioritize the types of BMPs that will provide the most rapid improvement in water quality of local rivers and ultimately the Chesapeake Bay. This process can be enhanced with improved scientific information (modeling, monitoring, and research) to further delineate areas of the watershed where BMPs will result in the most rapid improvement in water quality. There is also a need to communicate to citizens and tributary strategy teams the implications of the “lag times”

associated the Chesapeake Bay watershed and the potential for major events to overwhelm any water quality improvement that is slowly occurring due to BMP practice implementation and effectiveness. The communication of these concepts should help provide the patience and perseverance needed to improve the ecosystem of the Chesapeake Bay.

Appendix A

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Appendix B

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